RDECOM

Ground Systems Integration Domain (GSID) Materials for Ground Platforms

TARDEC

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Ms. Lisa Prokurat Franks
Materials Engineer
Office of the Chief Scientist

20 SEP 2010

Report Documentation Page

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Overview

Tank Automotive Research, Development & Engineering Center

Dr. Grace Bochenek, Director

TARDEC

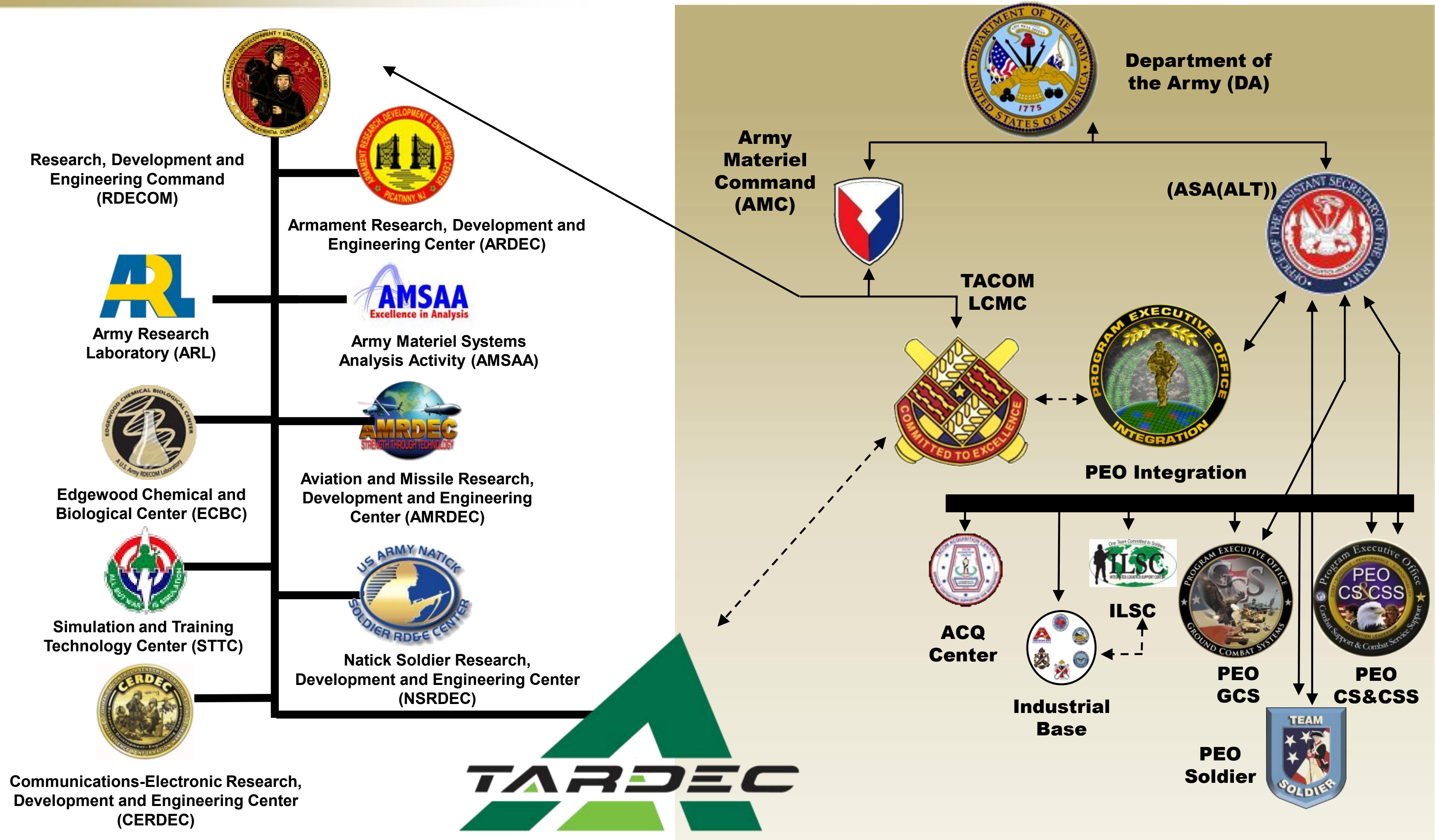
Mission

- Provides full life-cycle engineering support and is provider-of-first-choice for all DOD ground combat and combat support vehicle systems.
- Develops and integrates the right technology solutions to improve Current Force effectiveness and provide superior capabilities for the Future Force.

Ground Systems Integrator for the Department of Defense

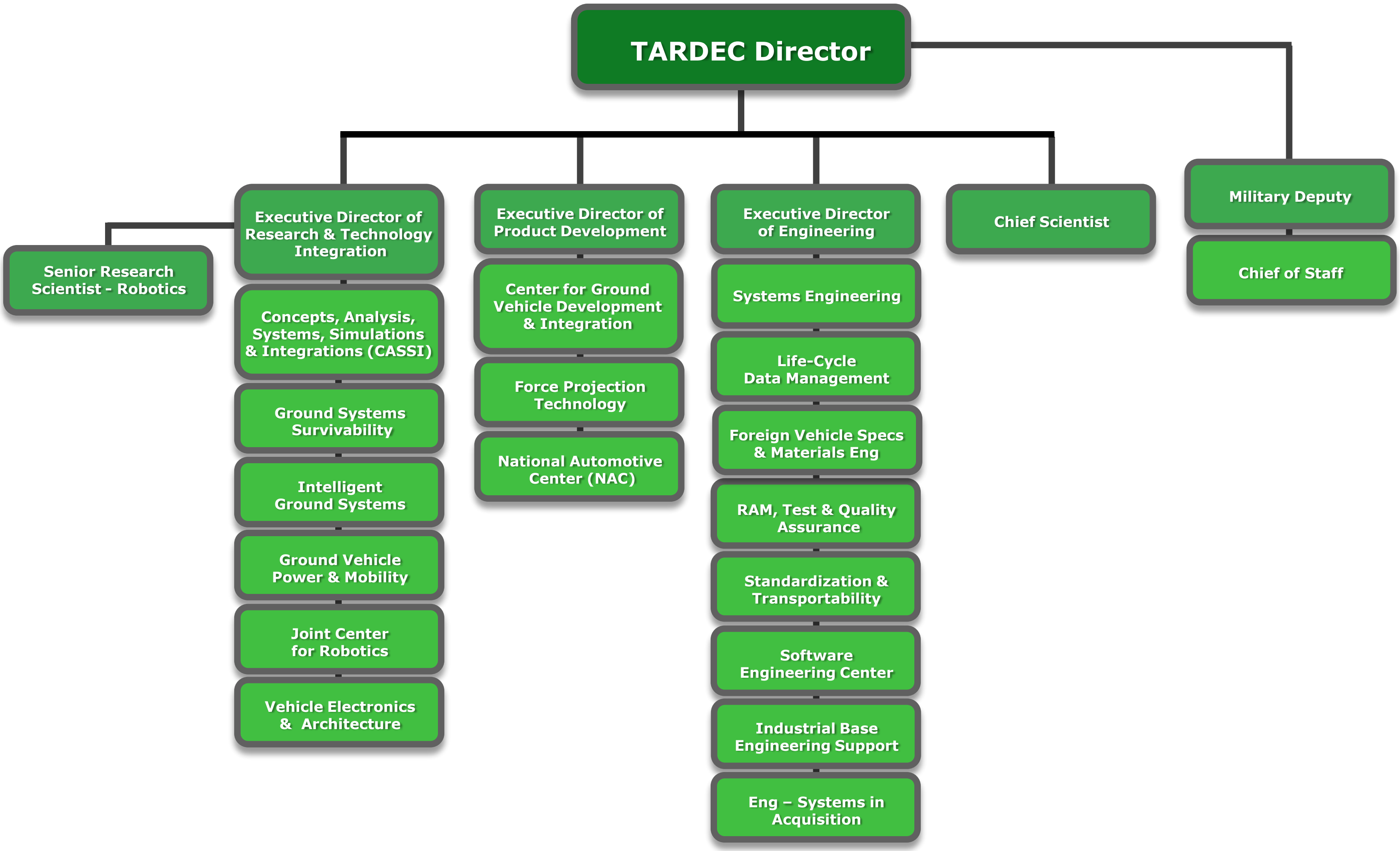
Responsible for Research, Development and Engineering Support to 2,800 Army systems and many of the Army's and DOD's Top Joint Warfighter Development Programs

Organizational Relationships



Reach back to over 8,500 Scientists and Engineers

Organizational Structure



Portfolio

Force Projection

- Fuel & Water Distribution
- Force Sustainment
- Construction Equipment
- Bridging
- Assured Mobility Systems

Combat Vehicles

- Heavy Brigade Combat Team
- Strykers
- MRAPs
- Ground Combat Vehicles (Future)

Tactical Vehicles

- HMMWVs
- Trailers
- Heavy, Medium and Light Tactical Vehicles

Robotics

- Technology Components
- Demonstrators
- Military Relevant Test & Experimentation
- Transition & Requirements Development

TARDEC Engineers Provide Cradle-To-Grave Engineering Support

Laboratory Capabilities

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System & Simulation Integration Laboratories

Concept Development

Modeling & Simulation Environment

System Evaluation

MRAP Systems Integration Lab

Survivability Laboratories


Ballistic Testing

Physical Simulation Laboratories

Reconfigurable N-Post Simulator

Multi-Axial Simulator

Vehicle Inertial Properties Evaluation Rig

Prototype Integration

Center for Ground Vehicle Development & Integration

Large Robotics Integration Cell

Fuels & Lubricants Laboratories

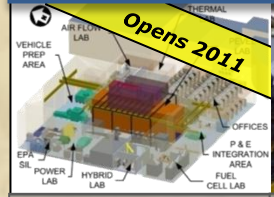
Coolant Lab

Grease & Hydraulic Fluid Lab

Fuel & Lube Lab

Analytical Lab

Power & Energy Laboratories



Ground Systems Power & Energy Lab

Propulsion Laboratories

TARDEC's Warren, MI operations has a resource value of over $950M and occupies 12 facilities on the Detroit Garrison totaling over 840,000 square feet of laboratory space

Material Initiatives and Needs for Lightening Ground Platforms

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Dr. Douglas Templeton
US Army TARDEC

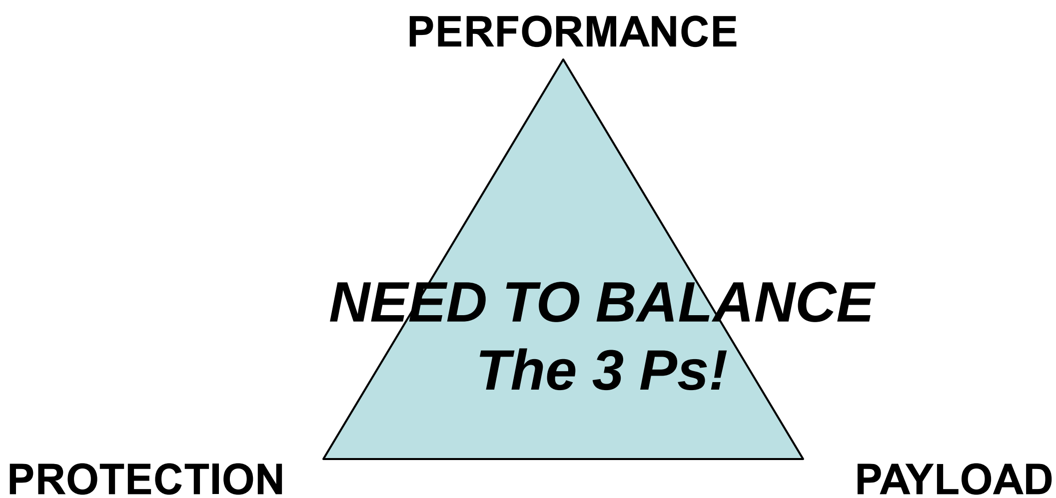
11 March 2010

UNCLASSIFIED: Dist A. Approved for public release

Motivation

DRIVERS

- **Lightweight/Mobile**
- **Threat Designable/Repairability**
- **Armor: Multifunctional Ballistic/Structural/Stealth**



Importance of Basic & Applied Research

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Basic Research

Applied Research

Adv Development

Eng Development

Brittle Materials:
- Material properties
- Processing/synthesis
- Ceramic optimization
- Failure mechanisms
- Failure morphology
- Dynamic behavior modeling
- Laboratory characterization techniques
- Determination of properties relevant to ballistic impact

Mechanics of Composites
- Finite element codes
- Strength of materials
- Analysis of thick composites
- Micro scale model

Penetration Mechanics:
- Constitutive material models
- Hi-strain rate propagation
- Metallurgy
- Hydrocode development

Armor Mechanics:
- -Defeat Mechanism
- Encapsulation Techniques
- Ceramic Optimization
- Multi-hit
- Structural Response
- Ballistic Shock
- Modeling
- Trends analyses
- Armor optimization
- Initial trades studies/analyses

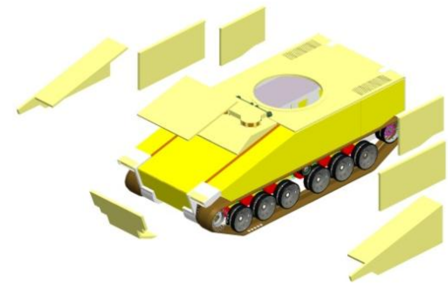
Structural Design Tech:
- Design trades
- LW structural Response

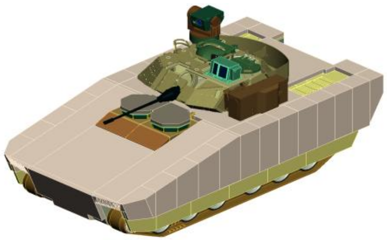
Armor module dev/fab
- Robustness
- Manufacturability
- Attachment design
- Shock transmission
- Affordability
- RAM

Structure
- Load optimization
- Attachment design
- Shock/vibration
- Damage tolerance
- Affordability
- RAM

Trades analyses
- Performance
- Weight
- Cost

Platform integration, producibility, and performance testing





IOC

INITIATION

*Basic research **critical** to success, and must be a **CONTINUING** activity*

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Materials for Ground Platforms

–Ideal situation: materials readily available and fully developed.

- RHA
- High hard steel
- Aluminum

–Reality: Research projects are ongoing to further develop advanced lightweight armors.

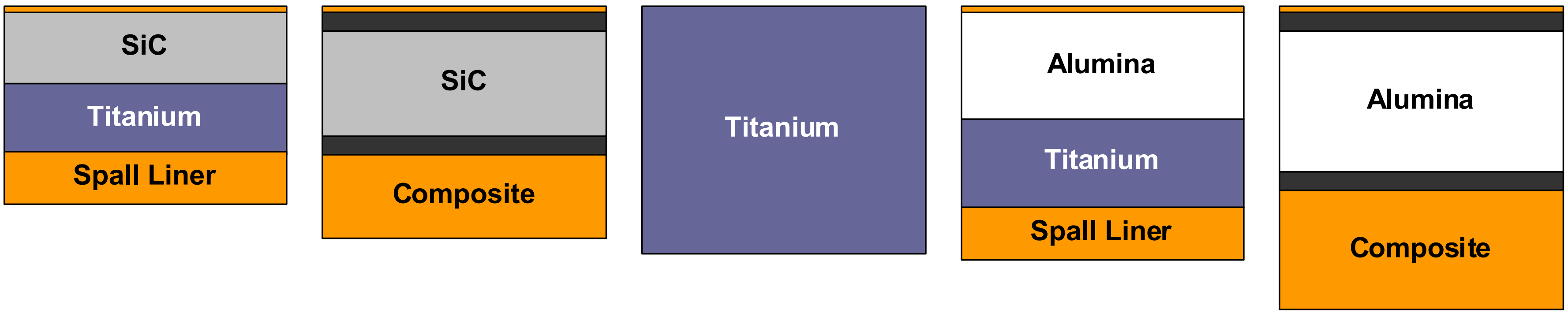
- Composites
- Ceramics
- Titanium
- Magnesium
- Composite and metal matrix

–Long Term Armor Strategy

- A + B design
- Requirements are classified

Design Drivers – Cost/Weight/Volume

- **Silicon Carbide Armor Tile Comparison at Equivalent Ballistic Protection**



20-23 psf	20 psf	40 psf	30-33 psf	30 psf
$80/lb*	$80/lb*	$30/lb*	$50/lb*	$35/lb*
1.0-1.5”	1.65”	1.75”	1.5-2.0”	2.15”

- (production cost)
- **Titanium & Aluminum/Lithium Alloy Raw Material Cost**

~$12/lb vs. ~$4/lb for Conventional Aluminum

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Structural Approaches

- **Space Frame**
  - –Lightest “structure only” weight
  - –Tailorable survivability
    - Ballistic armor tailored to mission requirements
    - Low burden integration of other enhancements.
  - –Ease of repair
  - –Improved transportability

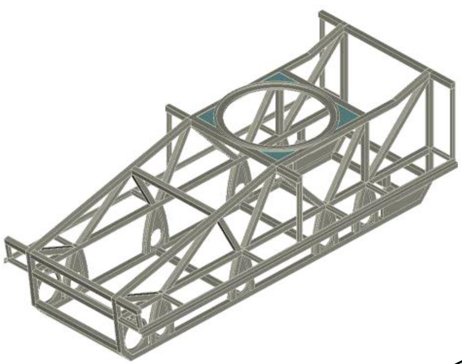
Monocoque

Lightest weight approach assuming a base level of ballistic protection

Efficient integrated structural armor solutions

Maximum interior volume

Lowest cost



Space Frame ⟵ **Hybrid Structures** ⟶ **Monocoque**

Combat Vehicles

Current

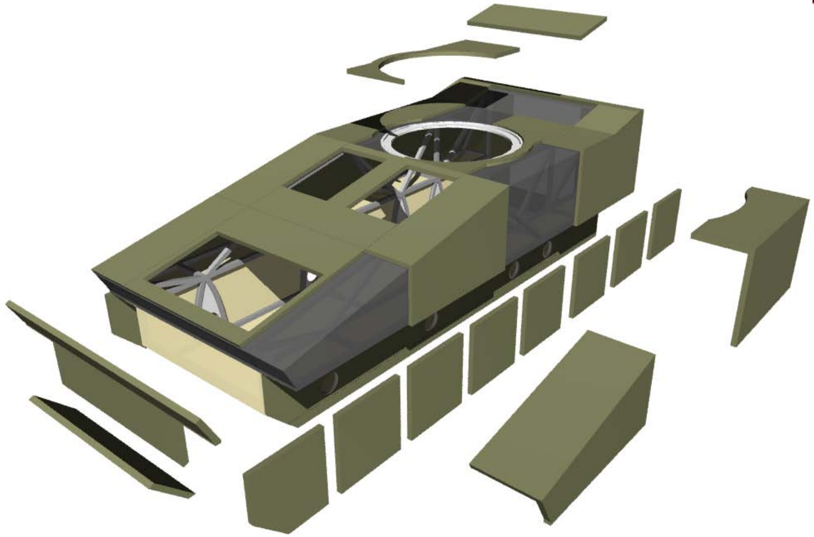
- Thick, heavy armor
- Structure as by-product of armor
- Inherently damage tolerant
- Arrive on ships
- Well understood materials and manufacturing practices
- Designed for force-on-force engagement
- Cumbersome logistics tail
- Basic situational awareness

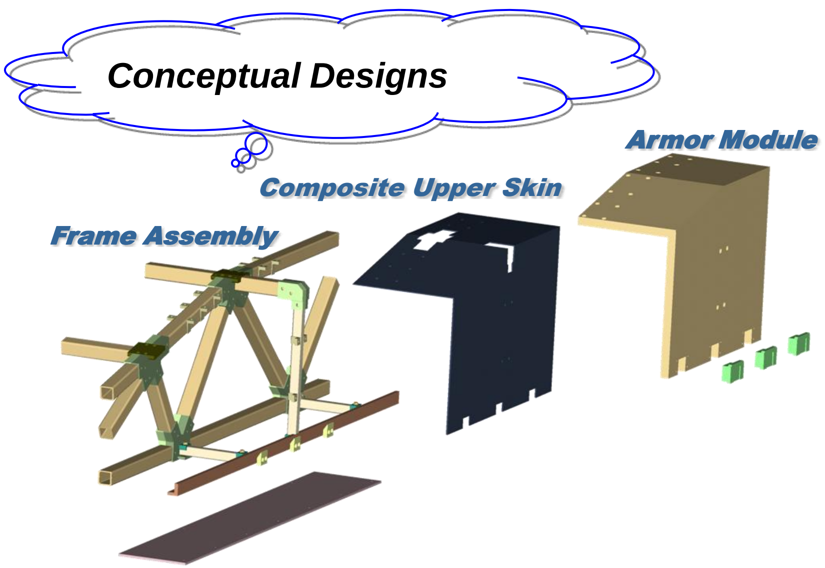
Future

- Lightweight armor
- Structure plus armor (A + B)
- Relatively damage intolerant
- Air transportable (C-130)
- Advanced ceramic armors, use of polymer composites and associated mfg. practices
- Designed for noncontiguous, non-linear, reorganizing battlefield
- Common components, reduction of logistics footprint
- Network centric, highly interdependent

Issues to Lightweighting Combat Vehicles

- Development of survivable vehicle systems while keeping to air transport weight (aircraft dependent)
- Attachment methodologies for A + B armor concept, appurtenances
- Joining and fastening technologies (dissimilar materials), adhesives
- Balancing interior volume against the use of less efficient structural material solutions
- Signature management, electromagnetic shielding over potentially non-metallic surfaces
- Diagnostics & prognostics for structural health assessment
- Material costs and improving multi-hit performance
- Advanced structures offer part consolidation necessitating development of high yield mfg. processes
- Inspection and repair of advanced armor systems
- Improved modeling and simulation





Tactical Vehicles

Current

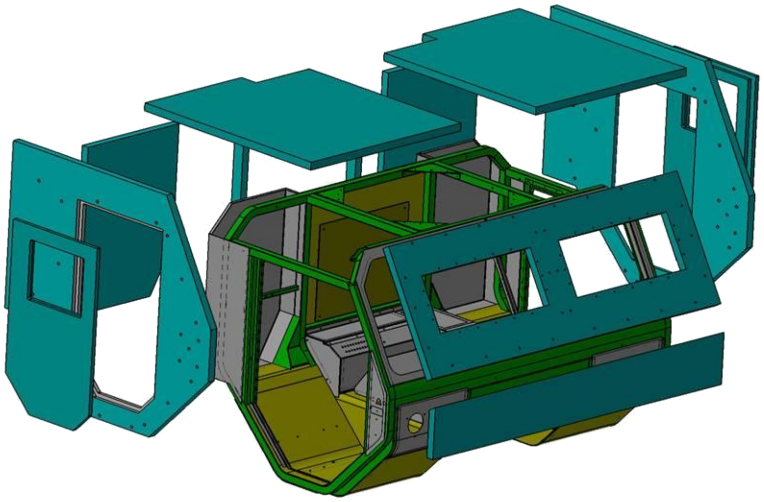
- Tired and aging fleet
- Corrosion prone
- Cabs typically unarmored. Armoring via add-on-armor kits
- Reduced vehicle payload, maneuverability, reliability, safety, maintainability, and life expectancy
  - Increased wear and tear on vehicle components, fuel consumption, and life cycle costs
- Multiple original equipment manufacturers, little commonality
  - Designed for traditional role of logistics support

Future

- Recapitalization with appliqué armor (A-kit/B-kit)
- Be more survivable in mine blast events
- Component commonality (hardware, transparent armor, B-kit panels
- Gun turret and advanced countermeasures
- Crew installable B-kit, with minimal tools
- Enhanced crew survivability to meet threat
- Increased system reliability
- Taking on more of an assault role

Issues to lightweighting Tactical Vehicles

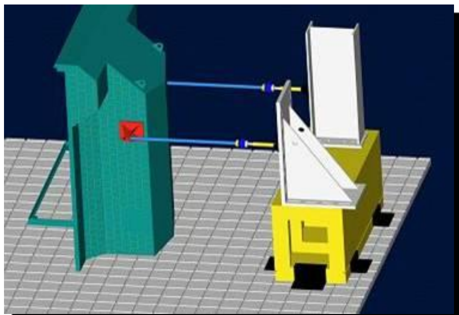
- Balancing material costs over a large vehicle fleet
- Integration of hybrid, advanced materials, and layered armor solutions
- A-frame with mounting points which allow for rapid addition/removal of B-kit, and spiral-in of emerging armor technologies
- Addressing seams and edges that result from modular armor
- Tile confinement for enhanced ceramic armor performance
- Improving armor multi-hit performance of advanced armors
- Opaque armors under 28 psf and transparent armors under 30 psf
- Keeping transparent armor thickness to a minimum
- Durability of advanced lightweight armors
- Health assessment of advance armors
- Improved modeling and simulation



A-Kit/B Kit Concept

Validated Design and Analysis Tools

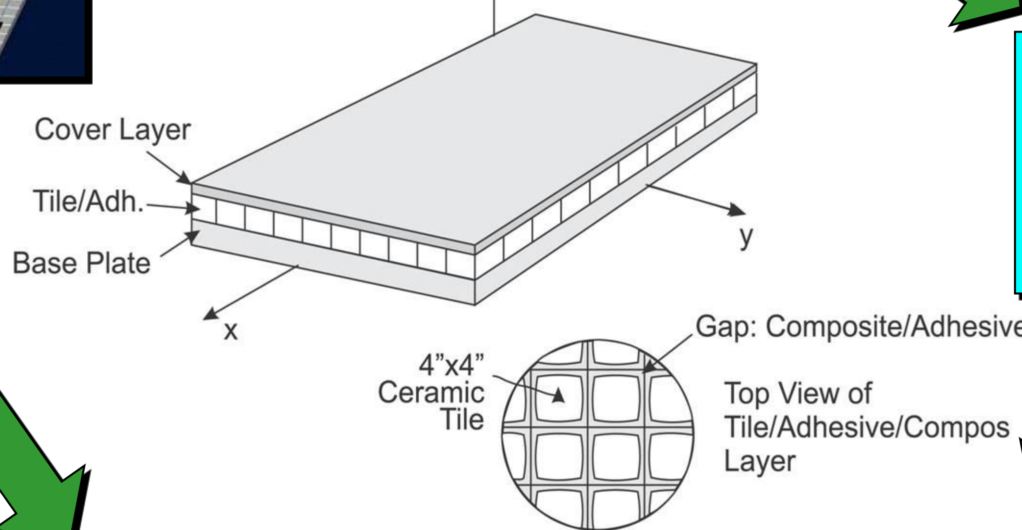
- Quarter Section Testing
  - Flexure
  - Shear
  - In-plane



Develop analysis tools critical for structural design

Sub-element Testing Required

Experimental Database for FEA



Database for Development and Validation of Laminate Modeling

SUMMARY
Of Material Initiatives and Needs for Lightening Ground Platforms

- Significant challenges remain in areas of material development
- Need to look at not just basic materials but structural approaches
- Modeling and simulation is a critical enabler

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Ground Systems Integration Domain (GSID)
Workshop on Materials for Ground Platforms

University Center - Macomb Community College
Clinton Township, MI

August 23-24, 2010

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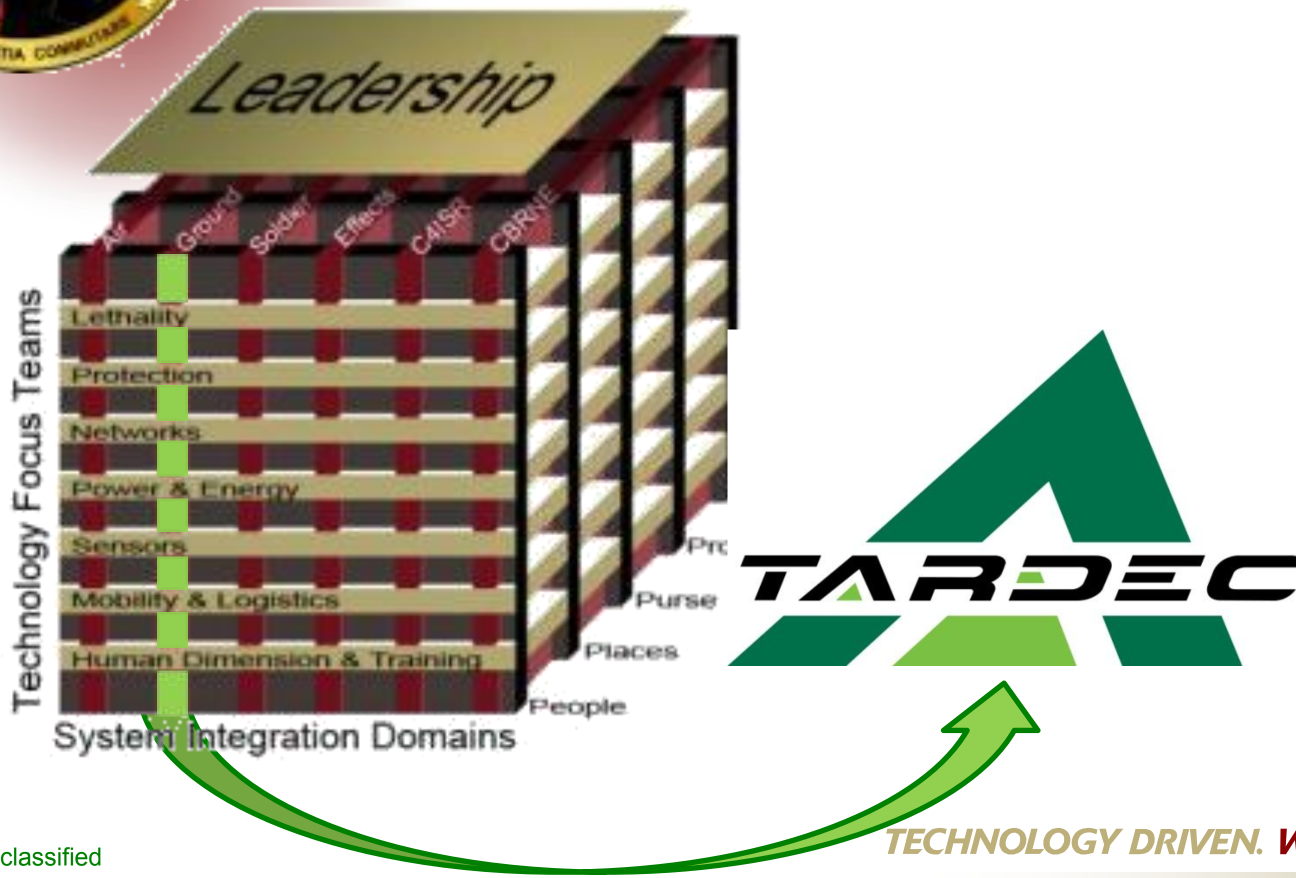
Ground Systems Integration Domain (GSID)



Holistic Approach to Ground Combat Vehicle Platform Innovation

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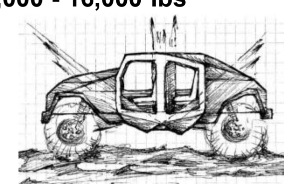
Driving Innovation across the Ground Community:

- Novel, inventive vehicle design approaches
- Rapid acquisition (12-18 month timelines)
- Extensive use of M&S tools to optimize design
- Non-tradition defense project partners
- Embedded with ARCIC to drive requirements generation for future platform requirements

Platform Weight Class	*Project Objectives*	*Project Partners*	*Project Schedule*
Heavy Combat 100,000 - 140,000 lbs	• Soldier-Centric Vehicle Design • Modular, Reconfigurable Vehicle Systems • Targeting selected GCV Objective Requirements	RDECOM *ACT VI Project*	• ~36 months from Concept to Design *(Includes tech development)*
Medium Combat 40,000 - 60,000 lbs	• S-MOD/MPC Threshold Survivability • Motor Sports Vehicle Design Process • M1 Equivalent Mobility	***Professional Motorsports Industry***	• 12-18 months from Concept to Build *(tentative)*
 **Light Tactical** 14,000 - 16,000 lbs	• FED Program–OSD Funded • 30% Fuel Economy Improvement over M1151 • Maintain Mobility of M1114	***Ricardo*** ***WTSI*** *Global Services*	• 12 month Tech Discovery phase • 18-24 months from Concept to Build
	• MRAP Threshold Survivability • <14,000 lbs Vehicle Weight • System Cost of $250,000	***Hardwire*** *Composite Armor Systems*	• 12 months from Design to Build

RDECOM will rapidly develop platform designs and demonstrators driving innovation in the areas of ground platform survivability and mobility.

Unclassified

Light Tactical Overarching Research Objectives

Primary Research Objectives (Occupant-Centric Survivability Focused):

- **Payload** — 1. 4500 lbs + trailer towing capacity; 4-6 man crew compartment
- **Performance** — 2. 14,000 lb curb vehicle weight
- **Protection** — 3. MRAP threshold survivability employing modular base armor
- **Price** — 4. $250,000 base vehicle (@ 10K Qty)
- **Schedule** — 5. 12 months

Projected Cost: $20M

Secondary Research Objectives (Light Tactical Vehicle Key System Attributes):

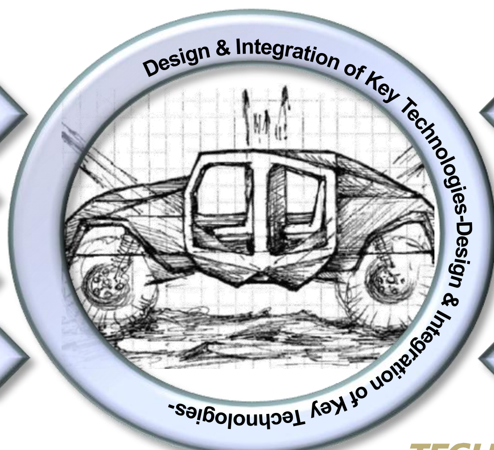
- **Performance** — 1. Select JLTV requirements as secondary research objectives

Double V-Shaped Hull

SBC (Lightweight Blast Mitigation System)

HDX Modular Armor (Spall, A-Kit, B-Kit, C-Kit & RPG Defeat Interface)

Virtual Transparent Armor



High-Energy Double Duty Lithium Ion Batteries

Hybrid Electric Propulsion System

Computer-controlled Magnetorheological (MR) Semi-Active Suspension

Modular Drivetrain & Suspension

Workshop Expectations

- Research Driven Opportunities
  - 6.1, 6.2 -> What should the GSID follow and support?
  - Awareness and participation in Material Science Programs

- Opportunities to integrate
  - Demonstrator programs (6.3)
  - Platform/Product/Part Driven Needs
    - PEO GCS, CS&CSS modernization programs
    - OEMs
    - DLA/Sustainment
    - Depots

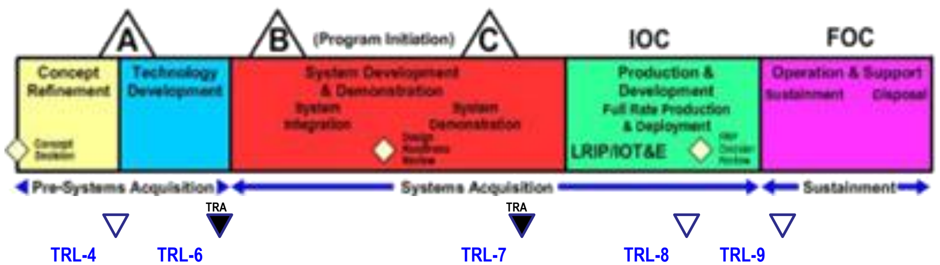
- Barriers to adoption of new materials?
  - Environment, safety, cost, weight, size, MRL/TRL

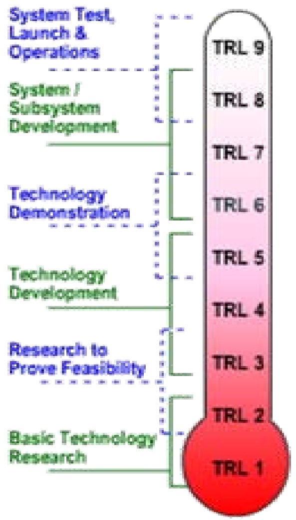
From PEO CS&CSS (23AUG 2010)

How to cross the "Valley of Death"

transitioning a technology into an acquisition program

- Most commonly from Army S&T (6.3 funded) TRL-6 to a Program of Record (6.4+)
- Know the Technology Readiness Level (TRL) of your technology





- Get to know the target platform
  - Where is the program in its lifecycle?
    - Determines the amount of each of the funding types available to the PM
    - Determines the maturity of the technology (TRL) the PM can accept (for example: TRL-6 at MS-B)
  - Technologies going into a POR undergo Technology Readiness Assessments (TRA)
  - What is the POR's acquisition strategy – COTS or Developmental?
  - PMs must have a requirement, validated by TRADOC, to acquire technology
- Understand the transition pathway – this is for you to have fully worked out
  - Does your technology have to be integrated in another manufacturer's system?
  - Can you manufacture your technology in quantity?
- Cost matters!

From PEO GCS (23AUG 2010)
Overarching

• Review of the ongoing activities in RDECOM, DARPA, academia, industry, partnering, and structured analysis to identify best opportunities-Funnel thru GSID

• Safety: During production through Hostile Engagement

• Primary: Power, survivability, communications, lethality

• Environmentally safe and nonhazardous

• Reflect heat, absorb solar energy to power batteries, shock absorbing (external and internal)

• EMI friendly so we can add antennas and retain low signatures

• Repeated heat/cold cycles.

From PEO GCS (23AUG 2010)
Prioritized Capability Gaps

Protection against asymmetric threats

Power and Electronics *

Mobility – Maneuverability

Fuel Efficiency

- Hit Avoidance
- Occupant Protection
- Unmanned Operations
- Armor
  - Energy Storage
  - Reliability/Maintainability/Sustainability
  - Assured Mobility
    - Protection against Kinetic
    - Force Projection

From PEO GCS (23AUG 2010)

-ilities for the Platforms

- New survivability materials must have good durability to last until needed Synergetic effects of armor metallic (AL, STL, TI) laminated with ballistic liners (Kevlar, E-glass, S-glass....)

- Reduced flammability: Don't put polyethylene base composite inside the vehicle such as Dyneema, Tenselon, Spectra

- Maintainability to allow field removal, replacement and/or repair: suitable chromium replacement

- Compatibility to resist corrosion and/or fungus

- Affordability with no negative impact on SWaP-C -lightweight structures

- Materials for power electronics'

–Suitable lead-free solder
–Efficiency and increase operating temperature(i.e. SiC, magnetics)
–Batteries to increase energy/power density(i.e. LiIon, energy dense cathodes)

- Polymers for suspension and track

- Lubricants: Single lube forward compatible with VHM Sensors

PEO Material Property Needs

- Strength
- Lightweight
- Manufacturable
- Maintainable
- Corrosion and fungus resistant
- Environmentally friendly
- Low-cost
- Reduced flammability materials
- Long life
- End-of-life plan

PEO Needs - Specifics

- Replacement for Cr
- Lead free solder
- Replacement for Halon
- Polymers for suspension and track
- Improved metals, glass, cloth
- Energy storage materials
- Bridging technologies – bridge, boat, trucks, health monitoring
- Propulsion systems to burn JP8 without sacrificing sensors
- Packaging for water and fuel
- Single lube compatible with existing sensors

R&D Agencies Represented

- ARDEC
- ARL
- ARL WMRD
- ARO
- DARPA
- DOE-ORNL
- DOE-PNNL
- DOE-VTP
- NIST
- PEO CS&CSS
- PEO GCS
- TARDEC
- USACE-ERDC

Lightweight materials

- Metals, alloys
  - Advanced High Strength Steels – many varieties
  - Titanium – needs work to produce inexpensively
  - Magnesium
  - Structural amorphous metals
- Non-Metals
  - Composites of every variety
    - Carbon fiber
    - Graphene
    - Glasses
    - Ceramics
    - Polymeric fibers
  - Boron carbide

Materials of the Future

- Nanomaterials
  - Nano grain sizes
  - Carbon
  - Coatings
- Bio-inspired materials
- Structured architectures
- Self-healing
- Damage sensing elastomers
- High-strength fibers
- Armors that spread the energy
- Foams, lattice materials
- Chemical manipulation
- Unprecedented properties
- Multi-materials

- Army started UARCs why? nsf?
- Schuh: work non-aqueous deposition
- Biotechnology
- Assumption: normal structures are ltwt;
- Low energy cons?
- How does DARPA see GSID helping itself? Ti initiative: structural amorphous metals (SAMS)
- Where is basic material science incubating? Universities: National labs?
- Controlling microstructure?
- Establish property – architectural specs?
- What is the process to bring new ideas and materials to the PMs, PEOs, etc?
- How does the basic research translate to useable materials?
- 61., 6.2, 6.3 appear to be stove piped: how to fix?

Workshop Expectations

- Research Driven Opportunities
  - 6.1, 6.2 -> What should the GSID follow and support?
  - Awareness and participation in Material Science Programs

- Opportunities to integrate
  - Demonstrator programs (6.3)
  - Platform/Product/Part Driven Needs
    - PEO GCS, CS&CSS modernization programs
    - OEMs
    - DLA/Sustainment
    - Depots

- Barriers to adoption of new materials?
  - Environment, safety, cost, weight, size, MRL/TRL

- It is a <u>Workshop</u>

GSID Expectations

- Opportunities
  - 6.2, 6.3
  - PEO GCS, CS&CSS
  - OEM
- Why do we have the heaviest SLAT armor?

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Needs

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- Stronger, lighterweight
- High energy storage devices
- Better processing
  - Lower cost manufacture methods
  - New technology forming methods
  - Joining – welding
- Models and Simulations
  - Understand structures
  - Predict materials and properties
- Testing
  - NDE
  - Accelerated corrosion testing
  - Available standards
  - Standardized test methods

Greatest Need

- A guide to traverse the Valley of Death
  - Requirements understood by researchers
  - Complete technical specs for new materials transferred to PEOs

Review of Issues/Actions from Day 1

- Both PEO's have commonality and SWAP-C needs
- Create GSID/PEO Integration Guide
- Avoiding the "Valley of Death" Guide
- Road mapping meetings?
- PEO TRA Support?
- Why is Value Engineering so Hard?
- Lightweight track ROI business case – share?
- Titanium path forward with DARPA
- P&E materials work skipped?
- Dan Morse – low temperature semiconductors
- Dr. Prater – materials by design
- Xtalic – quick win?
- Reversible damage sensing elastomer – Q-win?
- Tortorelli: CF8C – Plus steel – Cat – Q-win?
- What are transition issues to carbon fiber?
- Leveraging vehicle light weighting efforts